United States
Department of
Agriculture

Service Center
Modernization Initiative
(SCMI)

Map Accuracy Definitions

DRAFT

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Figure 1 — Working group list

RECORD OF CHANGE

Revision/ Change Number	Update Number	Change Date	Description/Reason for Change	Sections Affected

Table of Contents

List of Figures and Tables

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MAP ACCURACY DEFINITIONS

1. Overview

The goal of this standard is to establish map accuracy definitions for spatial data that will aid in managing United States Department of Agriculture (USDA) Service Center Modernization Initiative (SCMI) geospatial data. It supports the concurrent USDA Service Center Modernization Strategy to develop a basic nationally consistent set of core geospatial data that will provide a foundation on which to base business applications. The *USDA Service Center Geographic Information System (GIS) Strategy* [A5] first defined a list of geospatial datasets required to provide a foundation on which to base business applications. The *Geospatial Data Acquisition, Integration, and Delivery National Implementation Strategy Plan* [A1] further refined and expanded this list.

This document relates to other SCMI geospatial standards including SCMI Std 003, *Standard for Geospatial Data Set Metadata* [A2][1], SCMI Std 005, *Standard for Geospatial Feature Metadata* [A3], SCMI Std 007, *Standard for Geospatial Data* [A4], and the *USDA Service Center Initiative Directory Structure and File Naming Convention Change Control Policy* [A6]. It also relates to *Manual for Managing Geospatial Datasets in Service Centers* [A7]. These documents many appear to be dated but are still relevant and are revised as needed.

Appendix A of this standard provides bibliography references to the documents listed above.

1.1. Scope

The scope of this document is to define map accuracy for spatial data used by the Service Center Agencies (SCA). This document shall apply to the set of nationally consistent core geospatial data layers first defined in the *USDA Service Center Geographic Information System (GIS) Strategy* [A5].

1.2. Purpose

GIS for the Service Center comprises nationwide coverage of more than 20 common *geospatial datasets* (a group of similar spatial phenomena) that are collected and distributed at the county level of geography. These datasets all have actual or implied accuracy.

The purpose of this document is to specify terminology that will facilitate identifying sources of error in all maps, but primarily raster datasets. These terms will serve as a basis for standards and policy on assuring data accuracy in GIS applications managed by USDA. The goal is to enable customers to make correct visual interpretations of digital imagery and informed decisions about the quality of a map that may be produced from interpretations of imagery. The intended audience is SCA developers and project managers who contract for mapping software from commercial vendors. However, state GIS specialist, national offices, service centers, application developers, image contracting companies, etc. may find the document useful.

[1] The number in brackets corresponds to those of the bibliography in Appendix A.

This document will continue to evolve as nationally consistent datasets are provided to service centers. This document will be placed under configuration management and maintained through a structured change control process because the impact of changing this document can be great on those applications that use the data and those who provide the data. The change control process will allow proposed changes to be reviewed and discussed by those affected by the changes.

Nationally fielded applications will be developed by and for SCA that rely on the nationally consistent set of geospatial data. These applications will rely on the integrity of the data in abiding by the specifications in this document and subsequent standards and policy. Applications that are built locally for a Service Center or for data that is acquired locally shall adhere to these definitions.

1.3. Acronyms and abbreviations

CE	Circular Error
FSA	Farm Service Agency
GIS	Geographic Information System
GSD	Ground Sample Distance
LE	Linear Error
NAIP	National Agriculture Imagery Program
NDEP	National Digital Elevation Program
NMAS	National Map Accuracy Standards
NRCS	Natural Resources Conservation Service
NRI	Natural Resource Inventory
NSSDA	National Standard for Spatial Data Accuracy
RD	Rural Development
RMSE	Root Mean Square Error
SCA	Service Center Agencies (NRCS, FSA, RD)
SCMI	Service Center Modernization Initiative
USDA	United States Department of Agriculture
USGS	United States Geological Survey
UTM	Universal Transverse Mercator

2. Background

The Service Center Agencies are entering a new era with respect to the use of ortho imagery. Presently, USDA maintains technical control over the processing of imagery. The department has contracted commercial vendors and public agencies to collect imagery. Previously, the United States Geological Survey (USGS) was a key agency that provided data to USDA. The USDA exercised authority to post-process this imagery for use by its internal and external customers which ensured a level of quality.

Now USDA is presented with the opportunity to obtain complete national imagery databases from commercial vendors that have already performed the post-processing of digital imagery. In addition, the commercial operations offer to host the imagery on their own servers. These offers are particularly appealing in light of the budgetary restrictions with which the federal government is presented. Also, commercial vendors in some cases are better situated to technically manage the web farms that will see a large volume of activity. This opportunity presents a new challenge for USDA in ensuring the quality of imagery provided to its customers.

In essence, responsible managers will need to decide the amount of post-processing vendors will perform on data they supply to the agency. What level of quality do we specify as acceptable? To what extent do we partner with these organizations to achieve this level of quality? Viewing the post-processing that vendors perform as a black box is not the solution. Our obligation to our customers is to guarantee a specified level of accuracy. For programs such as National Agriculture Imagery Program (NAIP) and Natural Resource Inventory (NRI), this is already being done.

The ortho imagery has an effect on vector data sets that are produced from the imagery through heads-up digitizing. The resulting vector map data can not have a higher accuracy than the source image map. The vector interpretations are predicated on having accurate imagery to view.

3. Definitions

3.1. Accuracy

Often, a reference to an image's spatial resolution is mistakenly made as an expression of its accuracy. However, *accuracy* refers to the maximum error to be expected in the values of a dataset.[2] [A8]

There are two components of accuracy; vertical and horizontal. This document is primarily concerned with horizontal accuracy. Vertical accuracy is covered in detail in National Digital Elevation Program (NDEP), Guidelines for Digital Elevation Data [A9].

The accuracy of the dataset is made by comparing a sample of the data against reference information of known higher accuracy that is considered correct. As a result, an accuracy assessment is a statistical measure of the maximum amount of error that is expected to occur. It has two components:[3]

1. Magnitude of error that is calculated from the sample
2. Probability (confidence level) that the data will have accuracy equal to or greater than this magnitude (the confidence interval is usually 90 – 95 %)

The basic definition of accuracy can be expressed in absolute or relative terms, or as a threshold value.

The National Standard for Spatial Data Accuracy (NSSDA) [A10] uses root-mean-square error (RMSE) to estimate positional accuracy. RMSE is the square root of the average of the set of squared differences between dataset coordinate values and coordinate values from an independent source of higher accuracy for identical points.

3.1.1. Absolute Accuracy

Estimates of *absolute accuracy* are made in reference to the actual location of the feature on the ground. Based on this definition, absolute accuracy is said to reference 'true ground'.

Accuracy reporting in ground distances allows users to directly compare datasets of differing scales or resolutions. A simple statement of conformance (or omission, when a map or dataset is nonconforming) is not adequate in itself. Measures based on map characteristics, such as publication scale or contour interval, are no longer adequate when data can be readily manipulated and output to any scale or to different data formats.[4] This is especially true because maps now are primarily digital as opposed to analog where scale and contour interval statements are more relevant.

[2] "Remote Sensing for GIS Managers", by Stan Aronoff, page 99
[3] Ibid, page 101
[4] Excerpted from section 3.2.3 of the National Standard for Spatial Data Accuracy (NSSDA): Geospatial Positioning Accuracy Standards

3.1.2. Relative Accuracy

Relative accuracy states the accuracy of one theme relative to another theme. It is often used to express the accuracy of an overlay, e.g. vector layer, relative to a baseline image such as a raster backdrop.

Employing spatial data that are based on relative accuracy measurements could lead to less accurate visual interpretations. In the above mentioned case, the error within the overlay would compound any error that exists in the baseline image. For example, a vector overlay may have a relative accuracy vis-à-vis the baseline image of 5 meters. However, the baseline image's absolute error could be an additional 10 meters when referenced to true ground. The overall error for the composite dataset could be as much as 15 meters.

3.1.3. Threshold Accuracy

Threshold accuracy refers to the minimally acceptable data accuracy values for products, applications, and contracting services supplied to or developed by the federal government. The phrase 'threshold accuracy values' is synonymous with the phrase 'conformance levels'. Threshold accuracy is generally stated as a numeric value that is the starting point of acceptable accuracy.

The next two sections define two categories of accuracy that apply to spatial data.

3.2. Positional Accuracy

Positional Accuracy refers to the measurements of the location and size of features identified in an image. Positional accuracy has two main components:

1. *Horizontal Accuracy* – Refers to the horizontal difference between a test point on an image and the true location of a feature. The accuracy measurement is expressed in terms of radial distance or circular error (CE), because two dimensions need to be accounted for. X and Y coordinates for both the test point and the true position are used in the calculation.

   Example Definition – Measurements of the geographic position of features in an image are within 10cm of true ground position 95% of the time. The accuracy statement is expressed as 10cm CE95.

2. *Vertical Accuracy* – Refers to the elevation difference between the test point and the true position. This is a linear error (LE) measurement, since we are referring to one dimension. Vertical accuracies are used in reference to topographic imagery, such as contours.

   Vertical accuracy for contours @ 90% confidence[5]
   - Open areas – within ½ contour interval
   - Spot elevations – within ¼ contour interval

[5] This description uses the National Map Accuracy Standard of 1947, which can be used at agency discretion

Example – Contours are at 10 meter intervals. 90% of the samples:

- would have contours within 5 meters of their true elevation – 5m LE90
- would have spot elevations within 2.5 meters of their true elevation – 2.5m LE90

Note: Reference the "National Standard for Spatial Data Accuracy". This standard requires a 95% confidence level for horizontal and vertical accuracy. However, the specification of the allowable error is left to agency discretion. Usually, this standard is specified as an explicit distance such as of 0.5 millimeter or 1/50 inch at map scale.

3.3. Classification Accuracy

Classification Accuracy is the accuracy with which a feature is identified as belonging to a specific type or class such as forest or water.[6] Classification accuracy is also referred to as thematic or attribute accuracy.

3.4. Root-Mean-Square Error

The NSSDA uses root-mean-square error (RMSE) to estimate positional accuracy. RMSE is the square root of the average of the set of squared differences between dataset coordinate values and coordinate values from an independent source of higher accuracy for identical points.

Accuracy is reported in ground distances at the 95% confidence level. Accuracy reported at the 95% confidence level means that 95% of the positions in the dataset will have an error with respect to true ground position that is equal to or smaller than the reported accuracy value. The reported accuracy value reflects all uncertainties, including those introduced by geodetic control coordinates, compilation, and final computation of ground coordinate values in the product.[7]

The definitions in the following sections pertain to those factors that affect positional and classification accuracy.

3.5. Ground Sample Distance (GSD)

Ground Sample Distance (GSD) is defined as the distance across the area on the ground represented by a side of one pixel.[8] The unit of measure is usually meters or feet. An image that has a small GSD value exposes more detail, and is said to have a higher resolution. Ground Sample Distance is commonly referred to as *spatial resolution*.

However, GSD is not an expression of accuracy. GSD is one of several factors that affect the ability to perform visual interpretations. GSD certainly affects interpretability, but not always accuracy, unless the type of accuracy is further defined as either spatial or classification. See section 3.11 below for a description of the procedure that is recommended for presenting imagery that has the potential for being accurately interpreted.

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[6] "Remote Sensing for GIS Managers", by Stan Aronoff, page 101

[7] The definition below is excerpted from section 3.2.1 of the National Standard for Spatial Data Accuracy (NSSDA): Geospatial Positioning Accuracy Standards

[8] Remote Sensing for GIS Managers, by Stan Aranoff, pages 78 and 102

3.6. Scale

Scale is the ratio obtained by dividing the distance or area on a map (or image) by the corresponding equivalent distance or area on the ground. Depending upon the media used this would either be the *map scale* or the *image scale*.[9] Scale can be expressed in four ways: as a ratio, a fraction, in words and as a graphical (bar) scale. A scale in words can be called a lexical scale.

Some of the items discussed in this section on scale are more applicable to standard film aerial cameras but may not always apply to the multi-lens, multi-sensor systems. Pan-sharpened imagery would have different scale issues since different bands in the image could have been acquired under different resolution. The over all accuracy of the different bands in a pan-sharpened image could also be different.

Also note that image scale changes depending on whether or not the image on the screen has been georeferenced or orthorectified, and how it is being presented. In other words, ortho images don't really have a scale per se, because they can be zoomed in and out, and the distance of true ground that a pixel covers is the same. Yes, there is a scale on the screen, but it is a viewing scale, and is relatively meaningless in the same sense as a map scale.

3.7. Scale Factor

There are several definitions for scale factor. The appropriate definition depends upon the context:

Scale Factor Definitions:

A. A number that scales or multiplies some quantity[10]
B. The ratio obtained by dividing the actual scale at a particular place on a map by the stated scale of the map[11]
C. A value, less than 1.0, that converts a tangent projection to a secant projection[12]
D. A unit-less value applied to the center point or line of a map projection. It is usually 1.0 or less
E. The inverse of the map or image scale.[13]

These definitions indicate that Scale Factor is a number that is used to facilitate accurate interpretations when viewing imagery. The scale factor is a number that is applied (usually multiplied) to another number to minimize distortions of either shape, area, distance, direction, or some other relevant property. Depending upon the context in which it is used, this number can be stated as a ratio, a float, or an integer.

Definition A is a pure mathematical definition, presented for the sake of clarity.

Definition B can be applied in the context of viewing a map on a computer monitor

[9] Ibid, page 74
[10] Wikipedia definition
[11] "Dictionary of GIS Terminology, page 89, by ESRI Press
[12] Ibid, p. 89
[13] "Remote Sensing for GIS Managers", page 74, by Stan Aranoff

Example: Actual scale of the viewed map is 24000, while the stated scale is 30000
Result: Scale Factor is 24000 / 30000 = 0.80

Consequently, there is some distortion in the view, because the ideal is to have a ratio equal to 1.0.

Definition C is used for the purpose of reducing the distortions inherent in tangent projections. Secant projections are more accurate, because they generate two principal axes when the developable surface (a cone) contacts the globe.[14] The tangent projection has only one axis. The significance is that the axes represent contact points on the developable surface that are correct to scale. Therefore, more contact points result in greater data accuracy.

Definition D implies that the objective is to implement a scale factor of 1.0 across the entire Area of Interest (AOI). Deviations from this value lead to distortion. For the UTM projection, the scale factor at the central meridian is intentionally set at 0.9996 in order to avoid distortions at the edges of the UTM zone. This enables the east and west boundaries of the zone have a scale factor equal to 1.0. [15]

Definition E connotes a long integer. According to this definition, when the image is presented at a scale of 1:50000, the scale factor is 50000. This number represents the actual scale factor incorporated into the image or map. It should be compared to the optimal scale factor for presenting an image, given certain physical constraints. The key constraints are the GSD, i.e. the spatial resolution of the image, and the visual threshold of the medium that is used to present the image. For USDA's purposes, the medium is usually a computer monitor. The optimal scale factor is the product of the visual threshold and the GSD. [16]

optimal scale factor = visual threshold * GSD

Example: What is the optimal scale factor for a visual threshold of 300 pixels per inch and a Ground Sample Distance of 2 meters?

Optimal Scale Factor = (300 pixels/inch * 39.37 inch/meter) * 2 meters = 24000

Scale factors that are higher or lower than 24000 would result in more distortion, given the GSD and the visual threshold of the medium. Therefore, an image scale of 1:30000 that translates to a scale factor of 30000 is less desirable.

Spatial resolution (GSD) can affect visual interpretations, but is not a measure of data accuracy. It is a factor that determines the scale at which an image should be displayed or a potential viewing range. Conversely, the type of visual interpretation a user needs to perform will dictate the range of scales that is appropriate, and consequently what spatial resolution should be employed because it is inherent in the imagery.

Spatial resolution is one of several factors that influence the quality of visual interpretations. Some of the key factors include:

1. data collection techniques

[14] A developable surface is a surface that can be unfolded or rolled into a flat plane or sheet without stretching, tearing or shrinking. This mitigates distortions when projecting to the flat surface. Developable surfaces include cylinders, cones and disks. One map projection that employs a developable surface is Transverse Mercator.
[15] "Understanding Map Projections", page 20, by ESRI Press
[16] "Remote Sensing for GIS Managers", page 101, figure 4.27, and page 102, by Stan Aranoff

2. spatial resolution (GSD)
3. the map projection employed
4. the visual threshold of the display medium
5. the actual scale used to display imagery
6. the skill of the interpreter and the interpretation tools supplied to the interpreter

Items 1 and 3 in the list above have inherent data accuracy risks associated with them. Every projected coordinate system compromises at least one form of spatial data accuracy for the sake of preserving another. See Appendix B for a list of factors that affect data accuracy during data collection.

3.8. Ground Distance

Ground distance is a measure of accuracy when scale is factored.

Scenario – using a 1:50,000 scale map find the ground distance that conforms to the requirement to meet 0.5mm (millimeter) accuracy corresponding to a 90% confidence level.

The table below shows the ground distance accuracy and compares National Map Accuracy Standard (NMAS) and NSSDA. The table is from the National Digital Elevation Program (NDEP), Guidelines fro Digital Elevation Data.

The NSSDA does not address the suitability of data for any particular product, map scale, contour interval, or other application, no error thresholds are established by the standard. However, it is often helpful to use familiar NMAS thresholds for determining reasonable NSSDA accuracy requirements for various types of terrain and relief.

Map Scale	**NMAS** CMAS 90 percent confidence level Maximum Error Tolerance	**NSSDA** $RMSE_r$	**NSSDA** $Accuracy_r$ 95 percent confidence level
1" = 100' or 1:1,200	3.33 ft	2.20 ft or 67.0 cm	3.80 ft or 1.159 m
1 " = 200' or 1:2,400	6.67 ft	4.39 ft or 1.339 m	7.60 ft or 2.318 m
1" = 400' or 1:4,800	13.33 ft	8.79 ft or 2.678 m	15.21 ft or 4.635 m
1" = 500' or 1:6,000	16.67 ft	10.98 ft or 3.348 m	19.01 ft or 5.794 m
1" = 1000' or 1:12,000	33.33 ft	21.97 ft or 6.695 m	38.02 ft or 11.588 m
1" = 2000' or 1:24,000 *	40.00 ft	26.36 ft or 8.035 m	45.62 ft or 13.906 m

Table 3.1 — Ground Distance Accuracy

* The 1:24,000- and 1:25,000-scales of USGS 7.5-minute quadrangles are smaller than 1:20,000; therefore, the NMAS horizontal accuracy test for well-defined test points is based on 1/50 inch, rather than 1/30 inch for maps with scales larger than 1:20,000.

3.9. Collection Ground Sample Distance

Collection GSD is the distance represented by a pixel that is based solely on camera settings and the height at which the images were generated. It is also referred to as the *Camera Scale*. Mathematically speaking, it is the product of the camera detector element size and the scale factor.

GSD applies to standard film cameras and many digital sensors but is not be the case with sensors that do pan-sharpening. The “color” portion of the image may be acquired at one GSD and the panchromatic portion at a different GSD.

The scale factor is the ratio of the height flown above the ground divided by the focal length of the digital camera.

Example:
Camera lens focal length = 28 mm
Flying height = 1800 meters

Scale = 0.028 / 1800 = 1:65000
Scale Factor is equal to the inverse of Scale, i.e. 65000

Camera detector size = 0.009 mm
Scale factor = 65000

Collection GSD = 0.009 mm * 65000 = 0.6 meters

Images cannot be viewed at the collection GSD or camera scale, because they would be too small. Another scale needs to be calculated to determine proper viewing. It is called the product scale.

3.10. Product Scale

Product Scale is determined by measuring a feature in the product, e.g. computer monitor, and comparing it to the size of the feature on the ground. Specifically, it is the ratio of the product pixel size divided by the collection GSD. As stated above, the visual threshold for monitors is 300 pixels per inch. Therefore, the product pixel size would be 0.0000847 meters, if images on the monitor are displayed at the visual threshold. Using the example above the product scale would be:

Product Scale = product pixel size / collection GSD
Product Scale = 0.0000847 meters / 0.6 meters = 1:7000

The product scale is usually stated as the inverse, or 7000 in this example.

3.11. Procedure for Establishing Accurate Visual Interpretations

To reiterate, the goal is to create an environment in which accurate visual interpretations can be made by a customer. The abovementioned data accuracy definitions refer to the factors that affect our ability to do this. Below is a set of steps to follow for presenting data so that it can be accurately interpreted:

1. The analyst must determine what features are going to be interpreted and the type of interpretation that is to be done. See Appendix C for a detailed discussion of the different types of interpretations that a customer might perform.

2. Once these decisions are made the GIS analyst should have an idea about what spatial resolution is desired for representing the feature(s). Coinciding with this step, the analyst would determine whether imagery is available to supply the desired spatial resolution. The analyst would proceed to the next step, assuming imagery is available.

3. The analyst decides which product will render the image and determines its visual threshold. Once this is known, the spatial resolution and the visual threshold are factors that are used to determine the product scale that is needed to render the imagery (next step).

4. The analyst would calculate the product scale that is required to render the image such that the feature can be viewed at the desired resolution. See section 3.10 above for an example.

Note that the analyst can also refer to one of several charts supplied by GIS organizations to find the product scale. In this case the analyst would only need to know the spatial resolution (GSD), if the metrics in the chart are based upon the visual threshold of the same desired medium, e.g. a computer monitor.

These charts should also indicate the data accuracy for the imagery displayed at the product scale. As indicated above, spatial resolution and accuracy are related, but different metrics. An example will illuminate this point.

Example:

Refer to a chart supplied by Trimble Navigation LTD which provides values for product scale, spatial resolution and horizontal accuracy for a computer monitor display. The computer monitor's visual threshold is 1/300 of an inch. This means the unaided human eye can distinguish detail as fine as 1/300 inch on the monitor. Based upon this, below are the metrics predicated on a desired spatial resolution (all units are in meters):

- Spatial resolution (GSD) – 0.85
- Product Scale – 10,000
- Horizontal Accuracy – 8.5m CE90[17]
- Horizontal Accuracy for 1 Standard Deviation – 5.1m

The interpretation of the third bullet is as follows:

For a 1:10000 scale map, the geographic position as determined from the product for 90% of well-defined test points should fall within 8.5 meters of their true geographic position.

The interpretation of the last bullet is as follows:

[17] Ibid, page 88. This is what the National Map Accuracy Standard requires for a 10,000 scale map

For an image with a GSD of 0.85 meters, it would be expected that photogrammetric methods would generate maps with positional accuracies of 5.1 meters or better at the one standard deviation.[18]

Also note that the above procedure can be performed in reverse. In other words, there may be situations where the product scale has already been decided. The process would involve determining what spatial resolution (GSD) conforms to that scale. Using the above example, it can be derived as follows:

GSD = Scale Factor / Visual Threshold (pixels per meter)
GSD = 10000 / (300 pixels per inch * 39.37 inches per meter)
GSD = 10000 / 11811 = 0.85

3.12. Standards Publications and Organizations

3.12.1. National Standard for Spatial Data Accuracy

The Federal Geographic Data Committee (FGDC) ad hoc working group on spatial data accuracy developed this standard. This standard is an update to the U.S. National Map Accuracy Standard of 1947. The update incorporates the Accuracy Standards for Large-Scale Maps developed by the American Society for Photogrammetry and Remote Sensing (ASPRS) Specification and Standards Committee, 1998.

Below is an excerpt from the NSSDA:

"The geospatial data community has diversified to include many data producers with different product specifications and many data users with different application requirements. The NSSDA was developed to provide a common reporting mechanism so that users can directly compare datasets for their applications. It was realized that map-dependent measures of accuracy, such as publication scale and contour interval, were not fully applicable when digital geospatial data can be readily manipulated and output to any scale or data format. Principal changes included requirements to report numeric accuracy values; a composite statistic for horizontal accuracy, instead of component (x, y) accuracy, and alignment with emerging Federal Geographic Control Subcommittee (FGCS) accuracy standards (FGDC, 1998). The NCSSA was renamed the National Standard for Spatial Data Accuracy to emphasize its applicability to digital geospatial data as well as graphic maps.

The National Standard for Spatial Data Accuracy (NSSDA) implements a statistical and testing methodology for estimating the positional accuracy of points on maps and in digital geospatial data, with respect to georeferenced ground positions of higher accuracy.

The NSSDA applies to fully georeferenced maps and digital geospatial data, in either raster, point, or vector format, derived from sources such as aerial photographs, satellite imagery, and ground surveys. It provides a common language for reporting accuracy to facilitate the identification of spatial data for geographic applications.

This standard is classified as a **Data Usability Standard** by the Federal Geographic Data Committee Standards Reference Model. A Data Usability Standard describes how to express 'the

[18] Ibid,, page 88

applicability or essence of a dataset or data element' and includes 'data quality, assessment, accuracy, and reporting or documentation standards' (FGDC, 1996, p. 8)

Use the NSSDA to evaluate and report the positional accuracy of maps and geospatial data produced, revised, or disseminated by or for the Federal Government …."

As mentioned above, the NSSDA supersedes the NMAS. However, under certain circumstances responsible authorities may decide to apply the NMAS in lieu of NSSDA. Even so, they are encouraged to make data accuracy reports that conform to the NSSDA reporting specifications. In these cases, the NSSDA provides conversion tables. Appendix 3-D, section2, "Former Map Accuracy Standards (NMAS)" of Part 3: National Standard for Spatial Data Accuracy contains formula for converting NMAS to NSSDA data accuracy formats.

3.12.2. National Map Accuracy Standard (NMAS)

NMAS specifies a horizontal map accuracy standard as meters at 90% confidence at different map scales. For example, the horizontal accuracy standard at a map scale of 2400 @ CE90 is 2.0 meters. The size of the error can increase at *lower* map scales, i.e. lower ratios (the distance on the map divided by the distance on the ground).

3.12.3. Other Standards Organizations[19]

a. U.S. Geological Survey
b. American Society of Photogrammetry and Remote Sensing
c. Natural Resources Canada
d. U.S. Department of Transportation
e. State and Provincial Governments
f. Federal Geographic Data Committee

[19] Ibid page 102

4. USDA Data Accuracy Standards and Policy

One data accuracy standard will not properly address every visual interpretation scenario identified above. Therefore, a policy matrix for mapping geospatial data standards to different scenarios is required. This matrix is contained in USDA Directive Standard for Map Accuracy.[20]

[20] To Be Developed

Appendix A – Bibliography

When the following standards are superseded by an approved revision, the revision shall apply.

[A1] Geospatial Data Acquisition, Integration, and Delivery National Implementation Strategy Plan, Draft #4 Service Center Business Process Reengineering Data AID Team, September 22, 1999
http://www.itc.nrcs.usda.gov/scdm/docs/SPG-GeospatialDataAIDNationalStrategyPlan.pdf

[A2] SCMI Std 003, Standard for Geospatial Data Set Metadata
http://www.itc.nrcs.usda.gov/scdm/docs/SPG-GeospatialDatasetFileMetadata.pdf

[A3] SCMI Std 005, Standard for Geospatial Feature Metadata

[A4] SCMI Std 007, Standard for Geospatial Data
http://www.itc.nrcs.usda.gov/scdm/docs/SPG-GeospatialDataStandard.pdf

[A5] USDA Service Center Geographic Information System (GIS) Strategy, Interagency Team, August 18, 1998

[A6] USDA Service Center Initiative Directory Structure and File Naming Convention Change Control Policy, Initial Draft, IO Lab, October 8, 1999
http://www.itc.nrcs.usda.gov/scdm/docs/SPG-DirectoryStructureand%20FileNamingConventionChangeControlPolicy.pdf

[A7] Manual for Managing Geospatial Datasets in Service Centers
http://www.itc.nrcs.usda.gov/scdm/docs/SPG-ManualforManagingGeospatialDataSetsinServiceCenters.pdf

[A8] Stan Aronoff, 2005, Remote Sensing for GIS Managers, ESRI Press, ISBN: 1-58948-081-3
http://gis.esri.com/esripress/display/index.cfm?fuseaction=display&websiteID=97

[A9] Guidelines for Digital Elevation Data Version 1.0, National Digital Elevation Program (NDEP), May 10, 2004 http://www.ndep.gov/NDEP_Elevation_Guidelines_Ver1_10May2004.pdf

[A10] Geospatial Positioning Accuracy Standards, Part 3: National Standard for Spatial Data Accuracy, FGDC-STD-007.3-1998 http://www.fgdc.gov/standards/projects/FGDC-standards-projects/accuracy/part3

Appendix B – Image Data Capture

The factors affecting accuracy of imagery obtained from image data capture (aerial photographs and photogrammetric analysis) are the following:

1. *Scale* of imagery, which is affected by:
    a. flying height of platform
    b. focal length of the camera lens
    c. Sensor dimension and sensor pixel size
2. *Ground Resolution* of the imagery
    d. digital imagery – Ground Sample Distance (GSD)*
    e. film imagery – Ground Resolving Distance (GRD)[21]
3. *Base–height Ratio* – the degree of separation between two images of the stereo pair relative to the flying height
4. Accuracy of the ground control point measurements and digital elevation model
5. Performance characteristics of the photogrammetric instruments used. This includes Airborne GPS, IMU, scanning equipment, and ortho production software

[21] This is the size of the smallest feature that can be detected on film. GRD is calculated as Scale Factor divided by System Resolution (line pairs per millimeter). Example, GRD = 20,000 / 40 = 0.5 meters. Reference "Remote Sensing for GIS Managers, by Stan Aronoff", page 77.

Appendix C – Visual Interpretation

The objective of this section is to identify the relationship between image quality and visual interpretations. The specification of image quality is dependent upon what use will be made of the imagery.

1. *Fine-resolution* imagery is viewed at scales of 1:40,000 or larger. This imagery is useful when the following conditions exist:[22]
    a. Features are presented in their correct geometric relationships – geometric errors are removed.
    b. Detailed spatial information is provided – small parcels and fine detail are delineated, e.g. precision agriculture.
    c. Taxonomic detail is provided – e.g. separation of corn from wheat, oak from maple, etc.
    d. Spatial relationships between various realms of information are examined – relationships between vegetation distributions and water bodies, or between agricultural land and land devoted to residential development.
    e. Patterns of change over time are being monitored – changes in land cover or water quality
    f. Technical expertise is available to perform analyses – equipment and experienced staff are at hand to interpret imagery.

    Fine-resolution aerial imagery is not likely to be useful for the GIS manager when the following conditions exist:
    g. The data cannot be brought to a planimetrically correct geographic base, i.e. features can't be presented in their correct geometric relationships
    h. The imagery is to be used in a project where the data derived from the imagery is to be highly generalized or filtered to match datasets with coarser levels of detail.
    i. The imagery is to be used in a project where large regions require characterization at only course levels of detail, i.e. forest, farmland or water.
    j. The sponsoring agency is not prepared to invest in training or services to assure that necessary imagery, skills, equipment, and field support are available to conduct the interpretation.
2. On some occasions the imagery must support interpretations for situations where archive data, e.g. USGS data, is not sufficient. The user requires custom imagery. The data accuracy specifications are listed in a statement of work.
3. The imagery has to support criteria for performing visual interpretation. The criteria may consist of one or more of the following:
    a. Ability to define shapes
    b. Ability to determine the size of features
        1. Relative size
        2. Absolute size
    c. Ability to see tones, e.g. distinguish different crops
    d. Ability to see textures, e.g. see agricultural practices such as tilling or drainage
    e. Ability to see shadows
    f. Ability to site a feature (determine location with respect to topography and drainage)
    g. Ability to detect associated features (parking lots and shopping malls)

[22] Ibid, page 261
[22] Ibid, page 265, section titled "Classification"

   h. Ability to detect patterns of features, e.g. trees in an orchard
4. The imagery needs to support the interpreter’s ability to perform certain tasks:
   a. Classify objects - Often, the distinction is made between three levels of confidence and precision.”[23]
      1. *Detection* – the determination of the presence or absence of a feature
      2. *Recognition* – implies the interpreter can derive a more specific knowledge of the feature in question so that it can be assigned to a particular category.
      3. *Identification* – means that the interpreter can place the feature in a very narrowly defined class. Interpreters can convey their confidence in the interpretation using terms such as “possible” or “probable”.
   b. Enumerate discrete items
   c. Measure features
   d. Delineate features
5. Decisions must be made as to what additional information or support can be given the user to facilitate accurate interpretation.
   a. Image interpretation keys can be added to the user interface to clarify what is shown in the image:
      1. Technical keys
      2. Non-technical keys
      3. File keys
      4. Essay keys
      5. Dichotomous keys
   b. Define tools or techniques that can be used to perform image interpretations
      1. perform field observations
      2. supply heads-up (on screen) digitizing tools
         a. digital enlargement
         b. adjust contrast and brightness

In summary, the map’s or image’s scale will dictate what types of visual interpretations can be employed. On the next page is a table that provides guidelines for what types of interpretations are supported at different map scale ranges.

[23] Ibid, page 265, section titled “Classification”

Image Scale Range	Interpretations Supported
Small Scale – 1:50000 or lower scale	Reconnaissance Large area resource assessments General resource planning: 1. geological mapping 2. land use planning 3. agricultural monitoring 4. topographic mapping 5. forest monitoring
Medium Scale – 1:12000 to 1:50000	Identification Classification 1. mapping forest types 2. agricultural crop types 3. vegetation communities 4. soil types 5. surface materials 6. geology
Large Scale – 1:12000 and higher scale	Intensive monitoring and detailed measurements, such as: 1. engineering surveys for road construction 2. surveys for damage caused by natural disasters 3. surveys of diseased vegetation 4. hazardous waste spills

Table C.1 — Scale Ranges that Support Various Interpretations

Appendix D – Projection

The type of projected coordinate system used to create maps can significantly affect accuracy. A map projection is a device for representing all or part of an ellipsoid or sphere on a flat surface. The earth is accurately defined as an ellipsoid. A map projection would need to stretch, tear, or shrink an object that represents the earth in order to roll it into a two dimensional, flat plane. This distorts the image. The consequence is that a map projection cannot preserve both area and shape; one must be sacrificed for the other.

Since this cannot be done without distortion, a projection must be chosen for the characteristic which is to be shown accurately at the expense of others, or a compromise of several characteristics. Every system will preserve certain types of accuracy at the expense of others.

The characteristics normally considered in choosing a map projection are the following:

- *Area* – Map projections can be designed to be equal-area so that one part of the map covers exactly the area as another part of the map. This means that shapes, angles and scale must be distorted on most parts of the map.
- *Shape* – Many projections are conformal or orthomorphic in that the shape of every small feature is shown correctly. A large area will be shown distorted in shape even though small features are shaped correctly. An important point is that relative angles at each point and the local scale in every direction around any one point are constant.
- *Distance* – Equidistant maps preserve distances between certain points. Equidistant projections have one or more lines for which the length of the line on a map is the same length (at map scale) as the same line on the globe, regardless of whether it is a great or small circle or straight or curved. Such distances are said to be *true*. The lines usually fall along the parallels, the meridians or both, depending upon the projection. For example, in the Sinusoidal projection, the equator and all parallels are true lengths. However, no map projection is equidistant to and from all points on a map. [24]
- *Direction* – The shortest route between two points on a curved surface such as the earth is along the spherical equivalent of a straight line on a flat surface. That is the great circle on which the two points lie. True direction, or *azimuthal*, projections maintain some of the great circle arcs, giving the directions or azimuths of all points on the map correctly with respect to the center. Some true-direction projections are also conformal, equal area, or equidistant.[25]

On the next page is a list of select projected coordinate systems and descriptions of their adherence to data accuracy.

[24] Understanding Map Projections, page 12, by ESRI Corporation
[25] Ibid, page 12

Projected Coordinate System	Description	Uses
Mercator	1. Small shapes are accurate, local angular relationships are maintained 2. Area is distorted going towards the poles 3. Provides true direction lines, but does not provide shortest distance between points 4. Large area distortion 5. Useful in equatorial regions	1. Air travel 2. Wind direction 3. Ocean Current 4. Areas near equator
State Plane	1. U.S. only 2. A series of zones of projections which are either Transverse Mercator, Lambert Conformal Conic, or Hotine Oblique Mercator 3. Areas with a predominant north-south extent are Transverse Mercator, which preserves shapes, but not true directions 4. Areas with a predominant east –west extent are Lambert Conformal Conic, where shapes are more accurate than areas 5. Alaska’s panhandle is Hotine Oblique Mercator, where local shapes are true 6. Based on Clarke 1866 spheroid	1. east-west extents 2. north-south extents 3. Used in county and municipal government databases, so they will have coordinate systems that are in common with other databases that cover the same areas.
Universal Transverse Mercator (UTM)	1. An ellipsoidal Transverse Mercator 2. Not a projection but a series of zones of Transverse Mercator projections 3. Accurate representation of small shapes, with minimal distortion of large shapes within a UTM zone. 4. Area enlargement increases away from the tangent meridian	1. USDA 2. US Army 3. Where the north-south dimension is greater than the east-west dimension

Table D.1 — Descriptions of Selected Projected Coordinate Systems